



MULTIMODE TRANSMISSION SYSTEM  
USING TDMA

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## BACKGROUND ART

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## 10

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For example, a satellite beacon signal is required by a terminal to synchronize time for a TDMA satellite communications system. The beacon signal typically has its own waveform and is generated independent of data transmissions. To conserve satellite power, the beacon is allocated relatively  
5 low EIRP. To conserve spectrum, the beacon occupies a small fraction of the downlink bandwidth. To minimize interference with the main data transmission, the beacon is usually located at the edge of the allocated band.

In addition to the added complexity in the generation and recovery of the beacon signal, the conventional approach has a number of  
10 inherent problems. First, there is a concern with possible interference from the main data transmission. Second, a small bandwidth can limit the timing accuracy of the beacon. Finally, the timing biases between the data transmission and the beacon signal due to different hardware paths typically need to be calibrated and eliminated.

15 The disadvantages associated with these conventional satellite transmission techniques have made it apparent that a new technique for satellite multimode transmission using time division multiple access is needed. The new technique should reduce the number of antennas and modulators required in the satellite while improving transmission performance. Additionally, the new  
20 technique should reduce the number of antennas and demodulators required in the terminal and allow a single terminal, with a single antenna, to receive all types of satellite service. The present invention is directed to these ends.

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## SUMMARY OF THE INVENTION

It is, therefore, an object of the invention to provide an improved and reliable multimode transmission system using TDMA. Another object of the invention is to reduce the number of antennas and modulators required in a satellite. An additional object of the invention is to improve satellite transmission performance.

In accordance with the objects of this invention, a multimode transmission system using TDMA is provided. In one embodiment of the invention, A multimode transmission system using TDMA provides a plurality of satellite services to a ground station terminal. These services include timing beacon synchronization, multi-cast/broadcast data service, calibration data, and point-to-point data service. The multimode transmission system uses a TDM switch to generate a TDMA signal having a plurality of TDMA transmission frames. Each TDMA transmission frame includes a plurality of downlink frame time slots. Each time slot may be of variable length and is dynamically allocated to an individual satellite service based upon demand. The TDMA signal is then broadcast using an advanced transmit antenna system, which requires beam-shaping and beam power control features, to enable TDMA switching between shaped beams and spot beam modes of the antenna. These antenna features allow for the dynamic partitioning of satellite system capacity between wide-area broadcasts and localized point-to-point service and efficient utilization of the satellite transmission power.

The present invention thus achieves an improved multimode transmission system using TDMA. The present invention is advantageous in that it reduces the number of antennas and demodulators required in the terminal

and allows a single terminal, with a single antenna, to receive all types of satellite service.

Additional advantages and features of the present invention will become apparent from the description that follows, and may be realized by  
5 means of the instrumentalities and combinations particularly pointed out in the appended claims, taken in conjunction with the accompanying drawings.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

In order that the invention may be well understood, there will now be described some embodiments thereof, given by way of example,  
10 reference being made to the accompanying drawings, in which:

FIGURE 1 is a satellite system in accordance with one embodiment of the present invention;

FIGURE 2 is a block diagram of a multimode transmission system using TDMA in accordance with one embodiment of the present  
15 invention; and

FIGURE 3 is an aligned system TDMA framing structure and beacon frame in accordance with one embodiment of the present invention.

### **BEST MODES FOR CARRYING OUT THE INVENTION**

In the following figures, the same reference numerals will be  
20 used to identify identical components in the various views. The present invention is illustrated with respect to a multimode transmission system using TDMA, particularly suited for the aerospace field. However, the present

invention is applicable to various other uses that may require multimode transmission system using TDMA.

Referring to FIGURE 1, a perspective view of a satellite system 10 in accordance with one embodiment of the present invention is illustrated.

5 The satellite system 10 is comprised of one or more satellites 12 in communication with a ground station 14 located on the Earth 16. Each satellite 12 contains one or more multimode transmission systems 18 using TDMA for allowing a terminal located in ground station 14 to receive multiple satellite services.

10 In a satellite system 10 employing TDMA for multiple access for uplink and downlink transmission 20, data is sent in bursts on the allocated slots in a frame structure. Both satellite 12 and ground station 14 terminal receivers have a dynamic but limited capability to acquire and demodulate the signal within a single burst in the presence of time and frequency errors.

15 In a satellite-based scheme, the satellite 12 is the time and frequency reference for communication. Even when a satellite 12 is in geosynchronous orbit with a very small inclination, there are, however, Doppler induced frequency offset and varying time delays that would put signals outside the required limit if they were not corrected.

20 Referring to FIGURE 2, a block diagram of a multimode transmission system 18 using TDMA in accordance with one embodiment of the present invention is illustrated. Multimode transmission system 18 includes a time division multiplexed (TDM) switch 22, a pseudo-random number (PN) generator 24, a modulator 26, and an amplifier 28. Both the data and the beacon  
25 (PN sequence generated by PN generator 24) are generated in baseband. The





Furthermore, the present invention utilizes a contiguous bandwidth allocated for space-to-earth transmissions. The PTP service in general is operated with a modulated carrier whose symbol rate, error correction code (ECC), and pulse shaping occupy the entire bandwidth B. Other service  
5 modes (timing beacon, broadcast, calibration, and/or cell-cast mode) utilize either the same modulation or a modulation with a reduced symbol rate to ensure link closure. Although not strictly required, the symbol rate reductions are conceived to be integer factors such as  $1/2$ ,  $1/3$ , etc. to ensure timeslot alignment with an integer multiple of the full-rate timeslots (this facilitates  
10 system timing and control design). The ECC and pulse shaping filters may also be varied as required for optimum performance.

For timing beacon synchronization, the initial slot in the frame 42 is filled with a timing beacon synchronization pattern. During this timeslot 58, the antenna beam shape is set to a wide-area coverage broadcast shape.  
15 During the timing beacon slot 58, a reduced modulation symbol rate of  $1/3$  of the full rate modulation is used to ensure link performance over the wide-area beam. Note that for other narrower broadcast coverage regions (for example, with satellite operating over Europe, or Asia) the modulation symbol rate can be the full rate, or  $1/2$  rate, as required for link closure. Similarly, if a wider  
20 coverage is required a  $1/4$  rate modulation would be used, etc.

Terminals attempting to logon to the system acquire the system timing by searching for the timing beacon slot PN code. Further information on downlink formatting (i.e. the length of the various sections of the downlink frame) is then available via system messages contained in either the broadcast  
25 60 or PTP 64 section of the frame. A terminal may sort all successfully received messages for the address of the system information packet that contains the

downlink format, at which point the terminal may restrict it's message processing to the PTP section 64 of the downlink frame.

The TDMA beacon signal provides frequency and timing references to allow a terminal to synchronize itself with the satellite 12. With the satellite 12 as the reference, a satellite downlink frame 44 and the satellite uplink frame 46 is aligned with the beacon frame 48 at the satellite 12. M uplink frames 50 and N downlink frames 52 fit into a beacon frame 54. The synchronization relationship between the beacon 54, uplink 52 and downlink 50 frame is shown in Figure 1 for an example of M=4 and N=16. The TDMA beacon is inserted into a fixed slot of each downlink frame 44. As an example, the first slot of each downlink frame 44 is used for beacon frame 56.

A convenient means for time transfer is a pseudorandom (PN) sequence. Each of the beacon slots 58 contains a segment of a PN bit sequence that repeats on the beacon frame 56 as shown in Figure 3. A fixed initial state of the PN generator identifies the beginning of the first beacon slot in the beacon frame 56. After the PN sequence fills the last slot in the beacon frame 56, the PN generator is re-initialized with the fixed state.

After the TDMA beacon is recovered at the terminal, the locally generated PN clock reference is used as a terminal frequency reference that is coherent with the satellite, after compensating for Doppler. This approach mitigates the need for a highly stable frequency reference for the terminal.

Time is transferred from the satellite 12 via identifying the PN epoch with a time of day (TOD) value from a satellite broadcast message. Using the TOD and satellite ephemeris contained in the message, Doppler can be determined and corrected. The spacecraft 12 maintains the system TOD on-

board the spacecraft 12. The spacecraft 12 broadcasts the TOD information synchronized with the TDMA beacon.

For multi-cast/broadcast data service, each timeslot consists of N high-rate slots 60 (where N is an integer, for example N=3 for 1/3 rate modulation). During these broadcast timeslots 60, the antenna beam shape is set to a wide-area coverage broadcast shape. A reduced modulation symbol rate of 1/3 of the full rate modulation is used to ensure link performance over the wide-area beam. A single beam is radiated on each sense of circular polarization (LHCP and RHCP) so that interference is restricted to cross-polarized beam interference.

In a generalized multi-cast/broadcast data service, multiple shaped beams may be radiated. These multiple shaped beams would be narrower, the gains higher, the required RF power for all beams no greater than the total power available from the transmit antenna, and the co-polarized sidelobe performance of the beams would be compatible with link closure requirements for self-interference.

For calibration timeslot 62, a section of the DL frame 44 is dedicated for the calibration of the downlink transmit antenna 30. The specifics of the calibration method are not a subject of this particular application, but rather the general notion of embedding the calibration function into the TDMA downlink frame control. The manipulation of the antenna beam shape and individual antenna controls (beamforming amplitude/phase shifters, beam pointing or beam power control) occurs during this calibration timeslot 62 in coordination with ground measurement equipment.

For point-to-point data service, a section of the DL frame 44 is dedicated for the radiation of multiple narrow spot beams. A set of spot beams is radiated, on both polarizations (LHCP and RHCP). The spot beams are pointed to cover smaller downlink hexagonal cells. The pointing of the multiple beams is dynamically scheduled from the data queues in the satellite 12 on-board processor utilizing an interference-check mechanism that ensures sufficient distance between simultaneous downlink beams. A power check mechanism also ensures that the required power for the sum of the total spot beam is less than or equal to the total available RF power in the transmit antenna.

Within this portion of the downlink, the "cell-cast" function is also implemented. A system uplink cell for the example system in this application is a group of 7 smaller hexagonal downlink cells. Cell-cast is performed by dedicating a unique network packet address which corresponds to the central downlink cell within the group of 7 cells. The RF transmit power associated with this network address is raised by 3 to 4 dB to ensure link performance is met at the edge of the uplink cell (i.e. the group of 7 downlink cells). Normally, cell-cast transmissions are queued with other PTP data packet transmissions and scheduled for transmission in an identical fashion, which minimizes the impact of the cell-cast messages on data throughput. When an increase of 4 dB in the RF transmission power would violate the power flux density (PFD) limit imposed by FCC regulations, the cell-cast messages may be converted to 7-way multi-cast and the message sent 7 times once to each downlink cell.

There are also hybrid approaches wherein the 4 dB increased power cell-cast is used for some of the cells, and for the remaining cells (less than 7) a few multicasts are sent. Since the fraction of the footprint experiencing the heavy rain conditions is small, the amount of cell-cast traffic required to be 5 7-way replicated is small. One skilled in the art would realize that the specifics of the current example (e.g. 7 downlink cells per uplink cell) can be generalized to other structures (square cells, 19 hex cells per uplink cell, etc.).

The partitioning of system capacity across the various service types (i.e., broadcast and PTP, with embedded functions of timing beacon and 10 downlink antenna/RF calibration) is variable and will be commanded by the network operations and control center (NOCC). The timing beacon function is a fixed allocation, which defines the frame boundary by its location in time. The adjustment of broadcast and PTP capacity can be performed using current demand statistics combined with pre-scheduled hourly/daily data transfers, 15 and/or historical demand profiles. The calibration timeslot 62, occurring as shown between broadcast 60 and PTP 64 sections, may be present or not depending upon whether calibration is required. The overhead of any of these functions is small given the length of the DL data frame 44 is sufficiently long. Furthermore, one skilled in the art would realize that, the broadcast 60 and PTP 20 64 slots may be interspersed (interleaved, rather than contiguous).

The utilization of a downlink TDMA frame 44 also allows for the partitioning of system downlink capacity across the destination address space. One skilled in the art would realize that other possible utilizations of this functionality are possible. The capacity of the downlink may be arbitrarily 25 divided across destination addresses, so that hard partitions of capacity can be allocated to arbitrary groups of downlink PTP cells. Furthermore, given a large,

virtual address space, the capacity may be divided among service providers within the same sets of PTP cells by giving different timeslots to different service provider address groups. It should be noted that while this capability gives guaranteed capacity limits to each geographical region or to each virtual service provider, it reduces the statistical multiplexing performance, efficiency, and utilization of the total system capacity.

The method and system of the present invention provide for an improved multimode transmission system using TDMA. The present invention reduces the number of antennas and modulators required in a satellite while improving transmission performance. Additionally, the present invention reduces the number of antennas and demodulators required in a terminal and allows a single terminal, with a single antenna, to receive all types of satellite service.

From the foregoing, it can be seen that there has been brought to the art a new and improved multimode transmission system using TDMA. It is to be understood that the preceding description of the preferred embodiment is merely illustrative of some of the many specific embodiments that represent applications of the principles of the present invention. Clearly, numerous and other arrangements would be evident to those skilled in the art without departing from the scope of the invention as defined by the following claims:

**What is claimed is:**

- 1                   1.       A multimode transmission system using TDMA  
2 comprising:  
3                   a TDM switch coupled to a data signal, said data signal  
4 comprising a plurality of satellite services, said TDM switch multiplexing said  
5 data signal into a TDMA signal comprising a plurality of TDMA transmission  
6 frames, each TDMA transmission frame having a plurality of downlink frame  
7 time slots, wherein each of said downlink frame time slots is dynamically  
8 allocated to one of said plurality of satellite services;  
9                   a modulator coupled to said TDM switch and receiving said  
10 TDMA signal, said modulator modulating said TDMA signal to generate a  
11 modulated TDMA signal; and  
12                   a beam-shaping, power-controlling, transmit antenna coupled to  
13 said modulator and broadcasting said modulated TDMA signal using at least  
14 one downlink beam, said at least one downlink beam having a shape and  
15 number determined by said data signal.
- 1                   2.       The multimode transmission system using TDMA as  
2 recited in claim 1, wherein one of said plurality of services comprises a timing  
3 beacon synchronization data signal.
- 1                   3.       The multimode transmission system using TDMA as  
2 recited in claim 1, wherein one of said plurality of services comprises a multi-  
3 cast/broadcast data service.
- 1                   4.       The multimode transmission system using TDMA as  
2 recited in claim 3, wherein said multi-cast/broadcast data service comprises a  
3 cell-cast function.

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1                   5.     The multimode transmission system using TDMA as  
2     recited in claim 4, wherein said cell-cast function comprises multi-casting to  
3     individual downlink cells within an uplink cell.

1                   6.     The multimode transmission system using TDMA as  
2     recited in claim 1, wherein one of said plurality of services comprises a  
3     calibration data signal.

1                   7.     The multimode transmission system using TDMA as  
2     recited in claim 1, wherein one of said plurality of services comprises a point-to-  
3     point data service.

1                   8.     The multimode transmission system using TDMA as  
2     recited in claim 1, wherein each of said plurality of downlink frame time slots is  
3     a fixed length of time.

1                   9.     The multimode transmission system using TDMA as  
2     recited in claim 1, wherein each of said plurality of downlink frame time slots is  
3     a variable length of time.

1                   10.    The multimode transmission system using TDMA as  
2     recited in claim 1, wherein said at least one downlink beam has a variable power  
3     assigned to ensure link availability and bit-error-rate performance for a coverage  
4     area of said at least one downlink beam.

1                   11.    The multimode transmission system using TDMA as  
2     recited in claim 10, wherein a transmission information rate of is altered to  
3     ensure link availability and bit-error-rate performance for a coverage area of  
4     said at least one downlink beam.

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1                   12.     A satellite system comprising:  
2                   a ground station;  
3                   a satellite in orbit and in communication with said ground  
4 station, said satellite having a multimode transmission system using TDMA  
5 comprising:

6                   a TDM switch coupled to a data signal, said data signal  
7 comprising a plurality of satellite services, said TDM switch  
8 multiplexing said data signal into a TDMA signal comprising a plurality  
9 of TDMA transmission frames, each TDMA transmission frame having  
10 a plurality of downlink frame time slots, wherein each of said downlink  
11 frame time slots is dynamically allocated to one of said plurality of  
12 satellite services;

13                  a modulator coupled to said TDM switch and receiving  
14 said TDMA signal, said modulator modulating said TDMA signal to  
15 generate a modulated TDMA signal; and

16                  a beam-shaping, power-controlling, transmit antenna  
17 coupled to said modulator and broadcasting said modulated TDMA  
18 signal using at least one downlink beam, said at least one downlink  
19 beam having a shape and number determined by said data signal.

1                   13.     The satellite system as recited in claim 1, wherein one of  
2 said plurality of services comprises a timing beacon synchronization data signal.

1                   14.     The satellite system as recited in claim 1, wherein one of  
2 said plurality of services comprises a multi-cast/broadcast data service.

1                   15.     The satellite system as recited in claim 1, wherein one of  
2 said plurality of services comprises a calibration data signal.

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1                   16.    The satellite system as recited in claim 1, wherein one of  
2   said plurality of services comprises a point-to-point data service.

1                   17.    A method for satellite system synchronization comprising  
2   the steps of:

3                   generating a data signal comprising a plurality of satellite  
4   services;

5                   generating a timing signal;

6                   multiplexing said data signal to generate a TDMA signal having  
7   a plurality of downlink frames each downlink frame having a plurality of  
8   downlink frame slots, wherein each of said plurality of downlink frame slots is  
9   dynamically allocated to one of said plurality of satellite services;

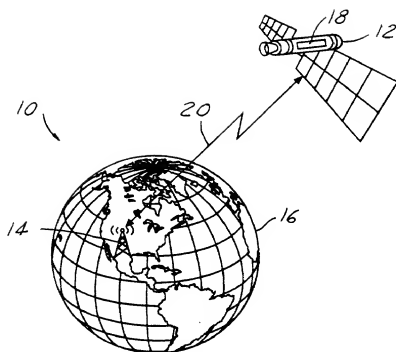
10                  modulating said TDMA signal to generate a modulated TDMA  
11   signal;

12                  broadcasting said modulated TDMA signal using at least one  
13   downlink beam, said at least one downlink beam having a shape and number  
14   determined by said data signal.

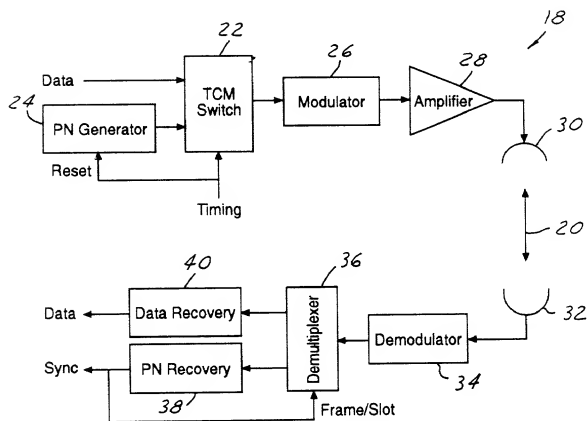
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### ABSTRACT

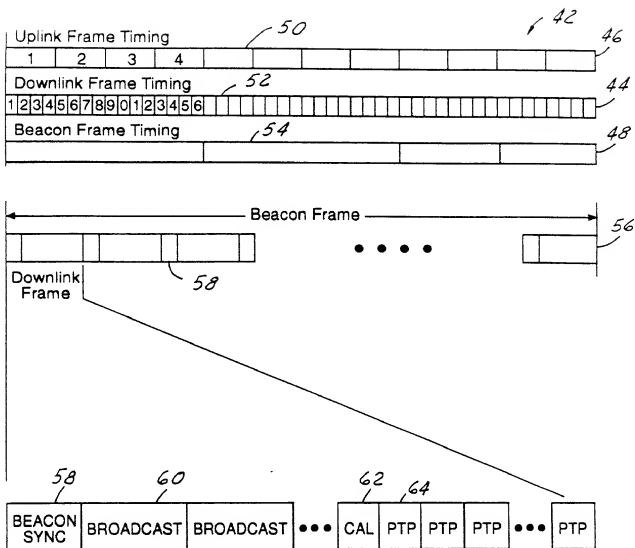
A multimode transmission system using TDMA provides a plurality of satellite services to a ground station terminal. These services include timing beacon synchronization, multi-cast/broadcast data service, calibration data, and point-to-point data service. The multimode transmission system uses a TDM switch to generate a TDMA signal having a plurality of TDMA transmission frames. Each TDMA transmission frame includes a plurality of downlink frame time slots. Each time slot may be of variable length and is dynamically allocated to an individual satellite service based upon demand. The TDMA signal is then broadcast using an advanced transmit antenna system, which requires beam-shaping and beam power control features, to enable TDMA switching between shaped beams and spot beam modes of the antenna. These antenna features allow for the dynamic partitioning of satellite system capacity between wide-area broadcasts and localized point-to-point service and efficient utilization of the satellite transmission power.



**FIG. 1**



**FIG. 2**



**FIG. 3**

Application Serial No.	Filing Date	Status (patented, pending, abandoned)
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I hereby declare that all statement made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such false statements may jeopardize the validity of the application or any patent issued thereon.

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